ELECTROMAGNET CORE AND METHOD OF MANUFACTURING THE SAME

Technical Field

[0001]

The present invention relates to an electromagnet core used for a liquid fuel injector and a method of manufacturing the electromagnet core.

Background Art

[0002]

Conventionally, an electromagnet core made of a powder composite material has been proposed. For example, there has been proposed a measuring valve control electromagnet used for a liquid fuel injector. The electromagnet includes a fixing core made of a magnetic material, an excitation core, and a valve activating armature. The fixing core is formed by pressing a mixture of a powder iron material and an epoxy binder. After the core is formed, the core is subject to a calcinations process. The powder iron material is made of ferrite. The epoxy binder is selected from various types of epoxy resins. The epoxy resin of from 2 wt% to 50 wt% is contained in the mixture.

[0003]

In addition, an iron power grain is covered with a thin phosphate layer (insulating film) having an electrical

insulating property. In addition, as an example, there has been proposed an iron powder grain containing a polymer additive (for example, polyimide or phenol resin) of 0.5 wt%.

[0004]

The epoxy binder or the polymer additive has an electrical insulating function and binds the grains. Due to high electric resistance between the powder grains, eddy current is not generated at the associated location.

[Patent Document 1] Japanese Unexamined Patent Application Publication No. H7-310621

[Patent Document 2] PCT Japanese Translation Patent Publication No. 2000-501570

Disclosure of the Invention

Problems to be Solved by the Invention

[0005]

A liquid fuel injector with an electromagnet is disposed on the way of a liquid fuel supply path. Therefore, an electromagnet core which is integrally installed in the liquid fuel injector may be in a direct contact with a liquid fuel or in contact with a vaporized gas of the liquid fuel. For the reason, a chemical resistance is required for the electromagnet core. On the other hand, the liquid fuel injector with the electromagnet core is integrally attached to an engine. Therefore, the

electromagnet is exposed to a high temperature, so that a heat resistance is required for the electromagnet core.

[0006]

The electromagnet core is formed by performing a pressing process on a mixture of a raw powder made of a soft magnetic material and a binder. As a volume ratio of the raw powder is higher, a performance of the electromagnet such magnetic permeability of magnetic flux density is more excellent.

[0007]

However, in the aforementioned conventional technique, since the binder for the raw powder is an epoxy resin, a polyimide resin, or a phenol resin having a heat resistance of from 50 to 160 °C, there is a problem in that the chemical resistance or the heat resistance of the electromagnet core is low. Therefore, the proposed electromagnet core has a limitation to use for the measuring valve control electromagnet used for a liquid fuel injector.

In a method of manufacturing an electromagnet core, a flow initiating material is mixed into the mixture of raw powder and binder in order to increase a flowing property thereof in a pressing process. However, the flow initiating material has a limitation to increasing the flowing property. As a result, the volume ratio of the raw powder in the electromagnet core must be further increased.

[0008]

In order to solve the aforementioned problems, an object of the present invention is to improve a chemical resistance and a heat resistance of an electromagnet core used for a liquid fuel injector. In addition, another object of the present invention is to increase a volume ratio of a raw powder by improving a flowing property of a mixture of a raw powder and a binder in a method of manufacturing an electromagnet core used for a liquid fuel injector which is formed by performing a pressing process on the mixture of the raw powder made of a soft magnetic material and the binder.

Means for Solving the Problems

[0009]

According to a first aspect of the present invention, there is provided an electromagnet core made of a soft magnetic material and including a coil, wherein the electromagnet core is formed with a soft magnetic powder and a binder for the soft magnetic powder, and the binder is made of a polyimide resin.

[0010]

According to a second aspect of the present invention, in the electromagnet core according to the first aspect, a volume ratio of the polyimide resin to the soft magnetic powder is in a range of from 0.05 wt% to 1.0 wt%.

[0011]

According to a third aspect of the present invention, in the electromagnet core according to the first or second aspect, the electromagnet core is used for a measuring valve control electromagnet used for a liquid fuel injector.

[0012]

According to a fourth aspect of the present invention, there is provided a method of manufacturing an electromagnet core made of a soft magnetic material and including a coil, the method comprising steps of: inserting a mixture of soft magnetic powder and a binder made of a polyimide resin into a molding frame; molding the mixture by using a pressing process, wherein a lubricant layer is formed on a surface of a receiving portion of the molding frame for receiving the mixture.

[0013]

According to a fifth aspect of the present invention, in the electromagnet core according to the fourth aspect, the receiving portion is heated from a room temperature to a high temperature, and before the mixture is inserted, the surface of the receiving portion is coated with a lubricant solution, and a moisture in the coated lubricant solution is vaporized by using a heat of the receiving portion, thereby forming the lubricant layer.

[0014]

According to a sixth aspect of the present invention, in the electromagnet core according to the fifth aspect, a

flow initiating material is added to the mixture.

Effect of the Invention

[0015]

According to the first aspect of the present invention, the polyimide resin having a thermally chemically stabilized molecular structure is used for the binder for the soft magnetic powder, so that it is possible to improve the heat resistance and the chemical resistance in comparison with a conventional core.

[0016]

According to the second aspect of the present invention, the volume ratio of the polyimide to the soft magnetic powder is in a range of from 0.05 wt% to 1.0 wt%, so that the molding can be effectively performed, and the volume ratio of the soft magnetic powder in the core can be secured.

[0017]

According to the third aspect of the present invention, since the electromagnet core having an improved heat resistance or chemical resistance is used as a valve control electromagnet of the liquid fuel injector, the injector attached to an engine can be effectively operated.

[0018]

According to the fourth aspect of the present invention, since the lubricant layer formed on surfaces of the receiving portion improves a lubricating property

between the soft magnetic powder and the surfaces, a friction between the soft magnetic powder and the surfaces caused by the press pressure at the molding process can be reduced. As a result, gaps between the grains of the soft magnetic powder and between the soft magnetic powder and the binder can be reduced at the molding process.

[0019]

According to the fifth aspect of the present invention, the lubricant layer is formed by vaporizing the moisture of the lubricant solution by using the heat of the receiving portion, so that a thickness of the lubricant layer can be reduced. As a result, the molding can be performed accurately.

[0020]

According to the sixth aspect of the present invention, the flow initiating material is added, so that the flowing property of the mixture at the pressing process or the like can be further improved. As a result, a density of the core can be further increased.

Best Mode for Carrying out the Invention

[0021]

Now, preferred embodiments of the present invention will be described. The scope and sprit of the present invention disclosed in claims is not limited to the embodiments described later. All the components described

layer is not intended to be essential components of the present invention.

First Embodiment

[0022]

Figs. 1 to 5 show a first embodiment of the present invention. An electromagnet 1 includes a core 2 and an excitation core 2. The core 2 has a shape of cylinder where a through hole 4 is formed along an axis z. A circular groove 5 is formed in on one side of the core 2 with a center thereof aligned with the axis z. A cylindrical coil 3 is inserted into the groove 5 in a concentric manner. A flanger 6 which is a moving member is disposed along the axis z. An armature 6a made of magnetite, or the like and having a shape of substantial disk is disposed on a distal end of the flanger 6, so that the armature can detachably contact one side surface of the coil 3 and one side surface of the core 2. When a current is applied to the coil 3, the electromagnet is excited, so that the flanger 6 is moved in the direction of the axis z. Referring to Fig. 5, when the current is applied to the coil 3, the armature 6a is suctioned into the electromagnet 1.

[0023]

The electromagnet 1 is disposed in an injector of a liquid fuel spray apparatus for an engine. As shown in Fig. 5, the injector 7 includes a valve body 9 which has a

liquid fuel spray hole 8 at a distal end thereof, a valve seat 10 which is formed in an inner end portion of the liquid fuel spray hole 8, and a needle-shaped valve 11 which is disposed in the valve body 9. In addition, the injector 7 includes an electromagnet 1 which drives the flanger 6 connected to the needle-shaped valve 11 for opening/closing the liquid fuel spray hole 8 and a return spring (not shown) for pressing the armature 6a and the flanger 6 so as to sustain the needle-shaped valve 11 in a closed state thereof. In addition, a liquid fuel supply hole 13 is disposed at the other side of the valve body 9. The liquid fuel supply hole 13 is connected to a liquid fuel pump (not shown). A liquid fuel F is supplied form the liquid fuel pump with a predetermined pressure thereof. In the injector 7, when the coil 3 is applied with a driving voltage and an excitation current, the armature 6a and the flanger 6 are suctioned into the excitation coil 3, so that the needle-shaped valve 11 allows the liquid fuel spray hole 8 to open. The needle-shaped valve 11 is maintained in the opened state until a magnetic field of the electromagnet 1 is removed. When the liquid fuel spray hole 8 opens, the liquid fuel is sprayed.

[0024]

The core 2 is formed by integrally fixing a soft magnetic powder 14 with a binder 15. The soft magnetic powder 14 is made of an electromagnetic soft iron or a silicon steel

which are relatively easy to magnetize or demagnetize. A insulating film 16 which magnetic force lines penetrate is formed on a surface of the soft magnetic powder 14. The binder 15 is made of a polyimide resin, that is, a polymer having a molecular structure where thermally, chemical stabilized imide rings (complex rings) or aromatic rings are disposed in a main chain thereof. A grain size (maximum width) of the soft magnetic powder 14 is in a range of from 10 μm to 200 μm, and more preferably, from 10 μm to 100 μm. This is because, if the grain size (maximum width) of the soft magnetic powder 14 is less than 10 μm, the manufacturing thereof is difficult, and if the grain size (maximum width) is more than 200 μm, sufficient resistivity cannot be obtained, so that sufficient strength cannot be obtained.

[0025]

The polyimide resin is made of a wholly aromatic polyimide, a bismalade polyimide, or an additive polyimide. The additive amount thereof is in a range of from 0.05 W% to 1.0 W%, and more preferably, from 0.1 wt% to 0.5 w%. This is because, if the polyimide resin is less than 0.05 wt%, the resistivity is not maintained, and if the polyimide resin is more than 1.0 wt%, a density thereof is not easily increased, so that the magnetic flux density and the permeability deteriorate.

[0026]

In addition, a flow initiating material 17 described later is mixed into the binder 15.

[0027]

Now, a method of manufacturing the core 2 is described. The molding frame 18 includes a female die 20 where a through hole 19 is formed, an upper punch 21, that is, a male die which is inserted into the through hole 19 in the downward direction thereof and a cylindrical core pin 22 and first to third ring-shaped lower punches 23, 24, and 25 which are which inserted into the though hole 19 in the upward direction thereof. The core pin 22 is disposed along an axis z' of the though hole 19, and an upper plane thereof is substantially aligned with an upper plane of the female die 20. The first lower punch 23 is disposed outside the core pin 22 in a concentric manner, and an upper plane 23a thereof constitutes a bottom surface thereof. The second lower punch 24 is disposed outside the first lower punch 23 in a concentric manner, and an upper plane 24a thereof is disposed to be higher than the upper plane 23a in order to form the groove 5. The third lower punch 25 is disposed outside the second lower punch 24 in a concentric manner, and an upper plane 25a thereof also constitutes the bottom surface similar to the upper plane 23a. On the other hand, a support hole 26 which the upper plane 22a of the core pin 22 is inserted into is formed on a lower surface of the upper punch 21 along the axis z'.

In addition, a heater 27, that is, heating means for maintaining the female die 20 in a predetermined temperature higher than a room temperature, for example, 120 °C is provided to the female die 20.

[0028]

In the manufacturing process, the core pin 22 and the first to third lower punches 23, 24, and 25 are inserted into the through hole 19 in advance, and a lubricant layer 29 is formed on a wall surface of the though 19 and a wall surface of a receiving portion 29 for receiving a raw material, that is, surfaces of the upper planes 23a, 24a, and 25a and inner and outer surfaces of the lower punch 24. More specifically, an aqueous lubricant solution 29a is sprayed from a spray hole 30 which is disposed on the upper plane of the female die 20 in the vicinity of the through whole 19 so as to coat the wall surface and surfaces of the receiving portion 20. Next, a moisture of the coated lubricant solution 29a vaporized by using the heat of the female 20, so that the lubricant layer 29 is formed on the wall surface of the through hole 19, the surfaces of the upper planes 23a, 24a, and 25a, and the inner and outer surfaces of the second lower punch 24. As a lubricant solution, an aqueous solution of 1% sodium benzoate or an aqueous solution of 1% potassium dihydrogen phosphate is used. The solution is sprayed and coated on the wall surface which is heated at 120 °C and vaporized, so that

the lubricant layer is formed as a crystallization layer on the wall surface

[0029]

In the state that the lubricant layer 29 is formed on the wall surface of the receiving portion 28 and the like, a mixture of the soft magnetic powder 14 which the insulating film 16 is formed, the binder, for example, 0.2 wt% additive polyimide region, and the flow initiating material, for example, 0.01 wt% ethylene bis-stearamide is dropped and received into the receiving portion 28.

[0030]

As a flow initiating material, a bisamide wax single substance such as ethylene bis-stearamide, ethylene bis-laurylamide, and methylene bis-stearamide or a mixture thereof is preferably used. This is because, the wax has a melting point of 140 °C or more, the monoamide material thereof has a low melting point, and the flowing property thereof is lowered due to the softening thereof by heat at a warm molding process. In addition, as an flow initiating material, a material formed by adding to 30% or less lithium stearate or 12 hydroxy lithium stearate to the wax (including a mixture thereof) is preferably used. This is because, the lithium stearate or 12 hydroxy lithium stearate improves the flowing property, the melting point of 220 °C is high, and the softening thereof does not occur. An additive amount of the flow initiating material is in a

range of from 0.002 wt% to 0.1 wt%, and more preferably, from 0.004 wt% to 0.05 wt%이, and a grain size (maximum width) of the flow initiating material is in a range of from 1 μm to 20 μm, and more preferably, from 1 μm to 10 μm. If the additive amount of the flow initiating material is less than 0.002 wt%, sufficient flowing property cannot be obtained, and if the additive amount is more that 0.1 wt%, sufficient strength cannot be obtained. If the grain size (maximum width) of the flow initiating material is less than 1 μm, the manufacturing thereof is difficult, and if the grain size is more than 20 μm, too much additive amount is needed to obtain the flowing property. In this case, sufficient strength cannot be obtained.

[0031]

Next, the upper punch 21 is inserted into the through hole 19 with a predetermined pressure, so that the core 2 is molded. During the molding, the soft magnetic powder 14 is in contact with the wall surface of the through hole 19 and also in contact with the outer surface of the core pin 22, the surfaces of the upper planes 23a, 24a, and 25a, and the inner and outer surfaces of the second lower punch. In the contacts, since the lubricant layer 29 is interposed between the soft magnetic powder 14 and the planes of the receiving portion 28, the soft magnetic powder 14 can be pressed in a lubricant state by the female die 20, the upper punch 21, and the first to third lower punches 23, 24,

and 25, so that the contact resistance at the planes and surfaces can be reduced. As a result, the press pressure can be reached into an inner portion of the molded body, that is, a pressed body, so that the volume ratio of the soft magnetic powder 14 per unit volume of the molded body can be increased. In addition, since the flow initiating material 17 is interposed between the soft magnetic powder 14 and the receiving portion 28, the press pressure can be reached into the inner portion of the molded body. In addition, the flow initiating material 17 is interposed between the soft magnetic powders 14 and between the soft magnetic powder 14 and the binder 15, so that the press pressure can be reached into the inner portion of the molded body.

[0032]

When the warm molding process ends, the upper punch 21 is lifted, and the first to third lower punches 23, 24, and 25 are lifted, so that the molded body (core) is extracted from the through hole 19.

[0033]

Now, a response characteristic (Fig. 5a) of the core according to the present invention and a response characteristic (Fig. 5b) of a sintered core are described with reference to Fig. 6. The core according to the present invention has a permeability of $\mu max = 6x10^{-4}$ H/m, a magnetic flux density of B 10 kA/m: 1.67T, and a

resistivity of 500 μΩm.

On the other hand, the sintered core has a permeability of μmax = $15x10^{-5}$ H/m, a magnetic flux density of B 10 kA/m: 1.57T, and a resistivity of 1 ~ 500 μΩm. As a result, the magnetic flux density of the core according to the present invention is close to that of iron, and the resistivity thereof is higher by 2 or 3 orders than that of a metal material. As shown in flanger lift amount Figs. 5a and 5b, the response characteristics at operation start and end times of the core according to the present invention is better than the sintered core.

[0034]

According to the aforementioned embodiment, the polyimide resin having a thermally chemically stabilized molecular structure is used for the binder 15 for the soft magnetic powder 14, so that it is possible to improve the heat resistance and the chemical resistance in comparison with a conventional core. In addition, the polyimide resin is used for the binder 15, and the volume ratio of the polyimide to the soft magnetic powder 14 is in a range of from 0.05 wt% to 1.0 wt%, so that a sufficient resistivity or strength can be obtained. As a result, the molding can be effectively performed. In addition, since the electromagnet 1 provided with the core 2 having an improved heat resistance or chemical resistance is used as a valve control electromagnet of the liquid fuel injector 7, the

injector attached to an engine can be effectively operated.

[0035]

In addition, since the lubricant layer 29 formed on surfaces of the through hole 28 or the like of the receiving portion 28 formed in the molding frame 18 improves a lubricating property between the soft magnetic powder 14 and the surfaces, a friction between the soft magnetic powder 14 and the surfaces of the through hole 28 or the like caused by the press pressure at the molding process can be reduced. As a result, gaps between grains of the soft magnetic powder 14 and between the soft magnetic powder 14 and the binder 15 can be reduced at the molding process. In addition, the lubricant layer 28 is formed by vaporizing the moisture of the coated lubricant solution 29a by using the heat of the receiving portion 28, so that a thickness of the lubricant layer 29 can be reduced and uniform. The flow initiating material 17 in addition to the soft magnetic powder 14 and the binder 15 is added, so that the flowing property of the mixture at the pressing process or the like can be further improved.

Industrial Usability

[0036]

An electromagnet core according to the present invention can be used for a measuring valve control electromagnet used for a liquid fuel injector or others.

Brief Description of the Drawings

[0037]

Fig. 1 is a perspective exploded view showing an electromagnet according to a first embodiment of the present invention.

Fig. 2 is a cross-sectional view showing a main construction of a core according to the first embodiment of the present invention.

Fig. 3 is a cross-sectional view showing a molding apparatus according to the first embodiment.

Fig. 4 is a cross-sectional view showing a main construction of a pressing process according to the first embodiment.

Fig. 5 is a schematic cross-sectional view showing a partially cut portion of an injector of a liquid fuel injection unit for an engine according to the first embodiment.

Fig. 6a is a graph showing a response characteristic of a core according to the present invention, and Fig. 6b is a graph showing a response characteristic of a sintered core.

Reference Numerals

[0038]

2: core

3: coil

7: liquid fuel injector

11: needle-shaped valve

14: magnetic powder

15: binder

17: flowing material

18: molding frame

28: receiving portion

29: lubricant layer

29a: lubricant solution